LAUTECH Journal of Civil and Environmental Studies **DOI: 10.36108/laujoces/2202.80.0111**
Volume 8, Issue 1; March, 2022

Hydrochemistry and Quality Assessment of Surface Water in Oba Dam, Ogbomoso, Southwestern Nigeria

[1*] Ogungbesan, G. O. and [1] Sanni, K. A.

[1] Department of Earth Sciences, Ladoke Akintola University of Technology, Ogbomoso, Oyo State, Nigeria.

[*] Corresponding Author E-mail: googungbesan@lautech.edu.ng Tel: 07066025569

Submitted on: 22/02/2022 *Accepted on: 31/03/2022*

Abstract
Hydrochemistry of the surface water in Oba Dam, Ogbomoso was investigated to determine the chemical characteristic and evaluate the water quality for drinking, domestic and agricultural usage. Twenty selected water samples collected at different points within the reservoir were analysed for pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS), Total Hardness (TH) and major ions (Na^+, K^+, Mg^{2+}, Ca^{2+}, Cl^-, NO_3^-, SO_4^{2-}, HCO_3). The pH values (6.5-7.9) of the samples suggest circumneutral to weakly alkaline nature of the water in Oba Dam. The cations are dominantly Na^+ and K^+, while the anions are mainly NO_3^-, Cl^- and SO_4^{2-}. The plot of the chemical data in Piper diagram revealed the water samples as Na-K-Cl water facie suggesting that the water chemistry is being controlled mainly by anthropogenic inputs. Comparing the analysed water samples with WHO and Nigerian water quality standards shows that all the chemical parameters were within the desirable limits for drinking purpose. Similarly, the computed water quality index (WQI) values (15-21) for the studied water samples suggest excellent quality for drinking and domestic purposes. Calculated parameters like sodium adsorption ratio (SAR), percent sodium (%Na) and Keller index (K1) reveal that most of the analysed water samples are suitable for irrigation usage. However, higher Na^+ content of few samples restrict the suitability for irrigation purposes. Therefore, this calls for regular monitoring of sodium contents to ascertain suitability for agricultural irrigation.

Keywords: Oba Dam, Ogbomoso, Hydrochemistry, Water quality, Irrigation suitability.

Introduction
Water is the most valuable natural resource, which is necessary for the well-being of all living organisms on the surface of the Earth (Du Plessis, 2017). Globally, over 70% of the Earth surface is covered by water in which about 97% of it reside in ocean as saline water (Mather, 1984) and unfit for both domestic and irrigation purposes. Almost 2.15% of the earth's water is frozen in ice caps and glaciers. The useable and available freshwater constituting 0.65% occupies lakes, streams, groundwater and atmosphere. Groundwater and surface water (lakes, rivers and stream) constitutes around 30% and 0.3% of the total available freshwater respectively (Cassardo and Jones, 2011; Du Plessis, 2017). Despite the meagre volume of fresh surface water, it constitutes the major source of supply for domestic and irrigation uses in many peri-urban and rural areas of sub-Saharan Africa.

The quality and availability of freshwater is one of the most persisting crises facing developing countries of the world. Water quality is an important factor in considering the usage of water for domestic, agricultural and industrial purposes (Tiwari *et al.*, 2017). The quality of water depends on concentration of its chemical constituents. The chemistry of surface water is said to be controlled by processes such as interaction with biomass, mineral weathering through rock-water interaction, atmospheric input and anthropogenic activities (Garrels and Mackeinzie, 1967; Gibbs, 1970; Aquilina *et al.*, 1997; Neal and Shand, 2002). Therefore, determination of concentration of major ions in water bodies can be used to investigate the water quality and identify the major processes that control the chemical distribution. In the last few decades, several studies have been carried out in different regions of the world focussing on hydrochemistry and quality assessment of rivers and basins (Akintola and Gbadegesin, 1997; Tijani and Onodera, 2009, Abegunrin *et al.*, 2016; Ojelabi *et al.*, 2018; Cao *et al.*, 2019; Kumar and Singh, 2020). However, limited information is available on chemistry and quality of surface water in the reservoir of Oba Dam (Akintola and Gbadegesin, 1997).

Oba earth-fill Dam was built is 1964 with the aim of providing water public water supply to Ogbomoso. The reservoir derives its water content from river Oba along the course of which it is built. The dam and its waterworks was built with capacity to supply Ogbomoso and its environs with about 4.0 million litres/day. Earlier study on the surface water in the dam suggested that change in land-use practices from natural forest to cultivated land around Oba Dam resulted in increasing contents of nitrate, nitrate-nitrogen and TDS over a period of time (Akintola and Gbadegesin, 1997). This present study is therefore motivated after over two decades that the last study was carried out. The study intends to carry out a detailed investigation of hydrochemical parameters of the surface water in the dam with a view of knowing the quality status as regards the use of the water for domestic, irrigation and industrial purposes. Given the adverse impact of contaminants on the utility of water and even human health, it is therefore, very valuable to investigate the hydrochemistry and assess the quality of community water source, which will be useful in making appropriate strategic decisions by stakeholders..

Location and Geology of the study area

Oba Dam is an earth-fill dam constructed in 1964 to supply potable water to Ogbomoso township. It is located between latitudes 8°9'N and 8°12'N and longitudes 4°9'E and 4°15'E (Figure 1). The dam is constructed within the channel of Oba River which supply the water for the reservoir. The embankment is 5m wide at its crest, 350 m long and 17 m high. The impounded area of the reservoir is 137.6 ha, with a drainage basin area of 321.2 km^2 and a storage capacity 3520 million litres of water (Akintola and Gbadegesin, 1997).

The dam area and the entire Ogbomoso town is located within the West African tropical climatic zone and therefore experience two distinct seasons; wet season which is from March to October with a brief dry spell in August and September, and dry season which runs from November to February. Annual mean temperature and rainfall around the study area are 26.2^0 C and 1200 mm with average relative humidity of 60%.

The study area is underlain by rock units of the Precambrian Basement Complex of southwestern Nigeria. These consist of dominantly migmatite gneiss, granite and quartz vein. The migmatite gneiss covers most of the area and specifically underlying the Oba Dam (Figure 1a). Next in abundance is the fine grained granites which are mostly exposed at the north-western part of the study area. The quartz vein occur as intrusion trending mainly in NE-SW within the granite.

Sampling and Analytical Methodology

Surface water samples were taken at 20 sampling points during a measurement and sampling campaign in December, 2018, starting from the under the bridge of Ogbomoso - Iluju road, southward to the embankment at the waterworks (Figure 1). Water samples were collected in 1L polyethylene bottles that has been washed with detergents, de-ionized water and finally rinsed with the surface water in Oba Dam. At each sampling point, the basic physical parameters like temperature, pH, total dissolved solids (TDS) and electrical conductivity (EC) were measure immediately after sampling using a portable digital meters. Each water sample taken were later divided into two. Portion kept for cation analysis was acidified to pH < 2 with 10% HNO_3. The samples were then labelled appropriately before taking to the laboratory. All samples were later stored in a refrigerator at the laboratory prior to analysis.

Major ions (K^+, Na^+, Mg^{2+}, Ca^{2+}, Cl^-, SO_4^{2-}, NO_3^- and HCO_3^-) were analysed according to standard procedures prescribed by APHA (2005) at SMO Laboratory Services in Ibadan, Nigeria. All water samples were firstly filtered through a 0.43 µm membrane and then analysed for cations using model 210VGP of the Buck Scientific AAS series; HCO_3^- and CO_3^{2-} (by acid titration); Cl^- (by $AgNO_3$ titration); NO_3^- (phenol-disulphuric acid colometric method) and SO_4^{2-} (by $BaCl_2$ titration). All the analyses were done in two replicates for each samples and results were rejected where standard deviation between the replicates is greater than 5%.

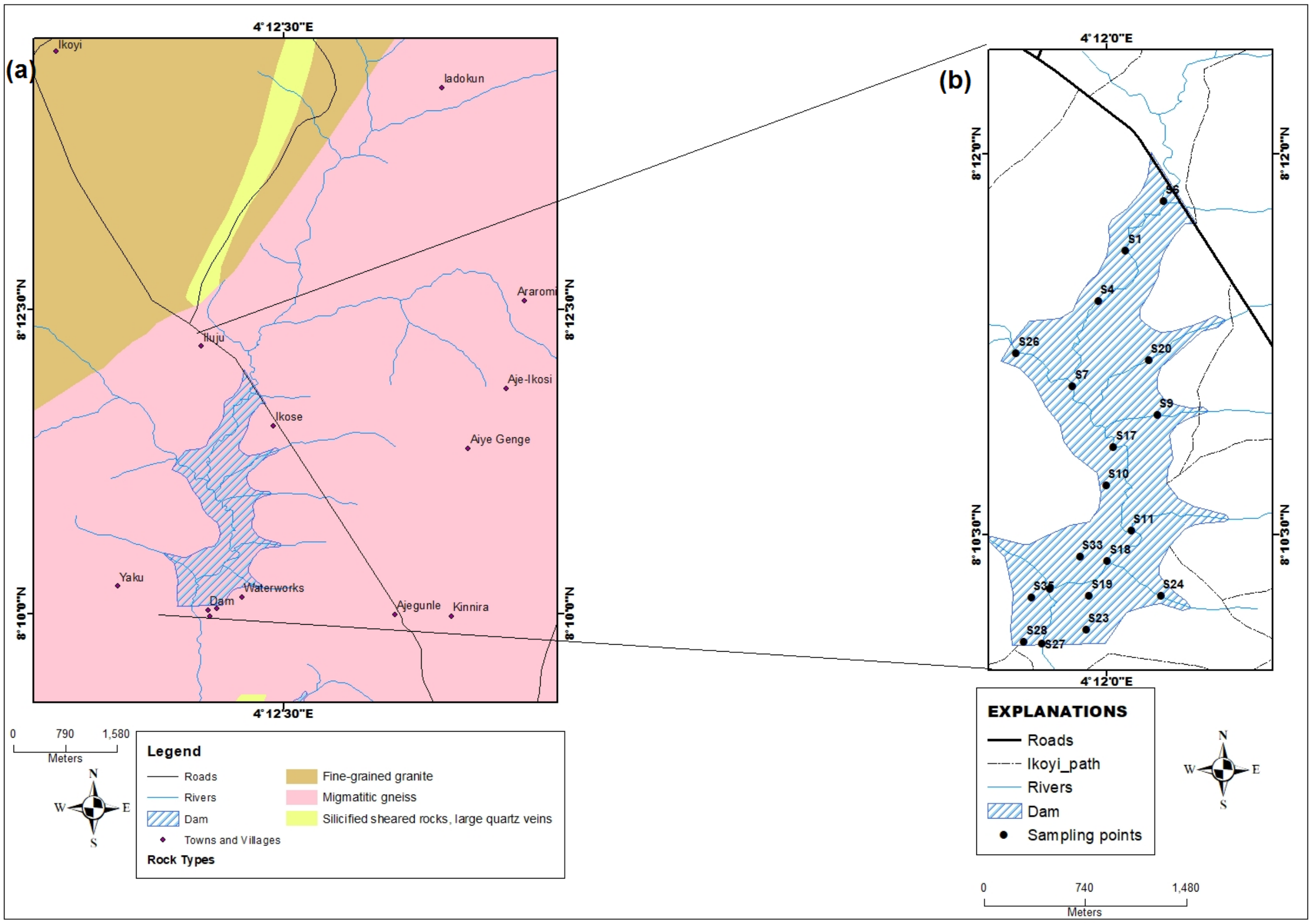

Figure 1: Maps of the study area (a) Geological map showing in addition to location of Oba Dam, distribution of rock types around the study area. (b) Location map showing water sampling points within the reservoir of Oba Dam.

Data Analysis and Quality Assessment Methods

The physiochemical data obtained were subjected to univariate (range, mean, standard deviation, coefficient of variation) and multivariate (Pearson correlation coefficient) statistical analyses using Excel 2007 and Statistical Package for Social Sciences (SPSS, version 16.0) software. Point density maps for the chemical data was produced using ArcGIS software. The quality of the surface water in Oba Dam for drinking purposes was examined based on percent compliance of measured parameters with World Health Organisation (WHO, 2011) and Standard Organisation of Nigeria (SON, 2015). The overall quality of the water for domestic usage was also evaluated by computing the Water Quality Index (WQI) of the samples as described in Batabyal and Charkraborty (2015) and Kawo and Karuppannan (2018). The irrigation suitability assessment of the surface water in Oba Dam was done using the following: sodium adsorption ratio (SAR), Percent sodium (%Na) and Keller index (K1).

SAR otherwise known as sodium hazard measures the degree of alkalization of irrigation water by quantifying relative activity of Na+ relative to Ca^{2+} and Mg^{2+} in soil exchange reactions (Subramani *et al.*, 2007). It is calculated using the equation

$$SAR = \frac{Na^{+}}{\sqrt{\frac{1}{2}(Ca^{2+}+Mg^{2+})}} \tag{1}$$

Where Na^{+}, Ca^{2+} and Mg^{2+} are expressed in milliequivalents per Litre (meq L^{-1}).
Richard (1954) classified the irrigation suitability of water based on calculated SAR values as excellent (<10), good (10-18), doubtful (19-26), and unsuitable (>26).

Percent sodium (%Na) otherwise known as sodium hazard is also widely used to assess water suitability for agricultural irrigation. It measures the relative ratio of sodium to other cations and calculated using

$$\%Na = \frac{Na^{+}}{Ca^{2+}+Mg^{2+}+Na^{+}+K^{+}}\ x\ 100\% \tag{2}$$

Where all the ionic concentrations are expressed in milliequivalents per litre (meq L^{-1}) of respective ions.

Similar to sodium hazard (%Na) is Keller index (K1) which measures the ratio of sodium to the sum of calcium and magnesium. K1 is calculated using

$$K1 = \frac{Na^{+}}{Ca^{2+}+Mg^{2+}} \tag{3}$$

Where all the ionic concentrations are expressed in milliequivalents per litre (meq L^{-1}) of respective ions. Water samples are classified as good for irrigation if K1 values are less than 1. Values greater than 1 indicate that there is too much sodium in the water and therefore, not suitable for irrigation.

Results and Discussion

Hydrochemical Characteristics

The statistical summary for the hydrochemical characteristics of the analysed surface water in Oba Dam is presented in Table 1. The pH values of the water samples ranged from 6.50 to 7.90, with a mean value of 7.22, suggesting circumneutral to weakly alkaline water. The electrical conductivity (EC) ranged from 130 to 280 µS/cm, with a mean value of 170 µS/cm. The total dissolved solids (TDS) values varied between 80 and 190 mg/L. All the samples have TDS values below the WHO permissible limit of 500 mg/L, indicating freshwater samples (Freeze and Cherry, 1979). Total hardness (TH as $CaCO_3$ mg/L) of the water samples ranged between 22.21 and 34.82 mg/L. All the analysed water samples recorded total hardness less than 60 mg/L and are thus classified soft.
The major ions contents of the water samples from Oba dam indicate that the anions are dominated by Nitrate (NO_3^-; 2.39-6.54 mg/L), followed by Chloride (Cl^-; 1.17-5.08 mg/L) and Sulphate (SO_4^{2-}; 0.58-4.05 mg/L) accounting on average 50.28, 26.44 and 18.94% of the total anion respectively (Figure 2a). Carbonate (CO_3^{2-}; 0.12-0.35 mg/L) and bicarbonate (HCO_3^-; 0.08-0.30 mg/L) are the least abundant ions representing on average 2.39 and 1.95% of the total anion respectively.

Table 1: Descriptive statistics of hydrochemical parameters for surface water in Oba dam.

Parameters	Min	Max	Mean	SD	CV (%)	WHO (2011)	SON (2015)
pH	6.50	7.90	7.22	0.46	6.33	6.5-8.5	6.5-8.5
EC (μS/m)	0.13	0.28	0.17	0.04	24.12	1000	1000
TDS (mg/L)	80.00	190.00	108.00	28.34	26.12	500	500
TH (mg/L)	22.21	34.82	26.16	3.50	13.38	50	-
Ca^{2+} (mg/L)	5.12	8.40	6.26	0.91	14.49	75	75
Mg^{2+} (mg/L)	2.19	3.36	2.56	0.37	14.63	50	20
Na^{+} (mg/L)	8.69	18.17	11.62	2.33	20.06	200	200
K^{+} (mg/L)	5.74	14.35	8.98	2.15	23.98	12	-
Cl^{-} (mg/L)	1.17	5.08	2.59	1.06	40.89	250	250
HCO_3^{-} (mg/L)	0.08	0.30	0.18	0.07	33.11	120	-
SO_4^{2-} (mg/L)	0.58	4.05	1.92	1.18	61.38	250	100
NO_3^{-} (mg/L)	2.39	6.54	4.87	1.26	25.94	50	50
CO_3^{2-} (mg/L)	0.12	0.35	0.22	0.07	33.11	-	-

The major cations contents are dominated by Sodium (Na^{+}; 8.69-18.17 mg/L), followed by Potassium (K^{+}; 5.74-14.35 mg/L) and then Calcium (Ca^{2+}; 5.12-8.40 mg/L) representing on average 39.37, 30.36 and 21.55% of the total cation respectively(Figure 2b). Magnesium ion (Mg^{2+}; 2.19-3.36 mg/L) is the least abundant accounting on average 8.73% of the total cations. All the major ions contents were lower than the WHO and SON standards for drinking water (Table 1). The coefficient of variation (CV) which reflects the degree of dispersion of the chemical parameters among samples, indicates that pH of the water samples is the only parameter that showed CV of less than 10%, suggesting weak spatial variability of pH values of surface water in Oba dam. The higher CVs values all ions (> 10%); particularly, the CVs of SO_4^{2-} and Cl^{-} (61% and 41%, respectively), indicate strong spatial variability of the ions in the analysed water samples, thereby suggesting the ions are very sensitive to environmental changes within the reservoir.

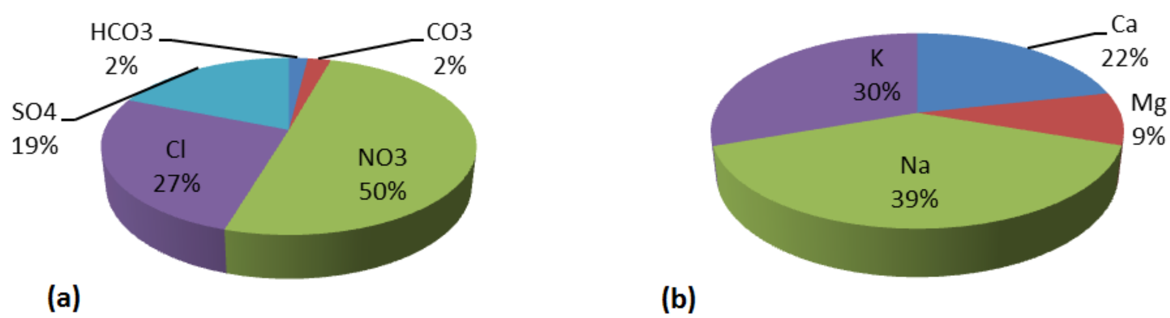

Figure 2: Percentage distribution of anions and cations to total anionic and cationic balance respectively

Multivariate Correlation Analysis: The Pearson correlation analysis among the chemical parameters of the analysed water samples shows significant positive correlation of TDS with Mg^{2+}, Na^{+}, K^{+} and NO_3^{-} (Table 2; r = 0.85, 0.89, 0.65 and 0.50, respectively), suggesting that the contents of the four ions contribute decisively to the values of the TDS in the water samples. The strong positive correlations among the Mg, Na and K (r = 0.6-0.9) suggest that they are likely supplied primarily via the same source and exhibit similar geochemical behaviour. Among the anions, NO_3^{-} shows positive correlation with Mg^{2+} and Na^{+} (r = 0.63 and 0.72, respectively) while HCO_3^{-} shows strong correlation with K^{+} (r = 0.55).

Hydrogeochemical Facies: In order to identify the evolving water types based on the geochemical characteristics of the major ions, the chemical data for the analysed water samples were plotted in the Piper diagram (Piper, 1944; Figure 3). The triangular cation plot of piper diagram reveals that all the water samples fall in ($Na^+ + K^+$) water class, whereas the triangular anion plot reveals that majority (75%) of the samples fall in Cl^- dominant class (Figure 3). The diamond-shaped piper plot classifies the surface water in the study area into the Na-K-Cl water facie. This suggest that the surface water in Oba dam is characterized significantly by more alkali elements (Na^++K^+) than alkaline earth elements (Ca^{2+}+Mg^{2+}), and strong acid (SO_4^{2-}+Cl^-) exceed weak acid (HCO_3^-). The Na-K-Cl facie type of the water samples in Oba Dam suggest ionic source dominantly from anthropogenic activities around the study area.

Table 2: Correlation matrix of hydrochemical parameters for the analysed water samples

	pH	EC	TDS	Ca^{2+}	Mg^{2+}	Na^+	K^+	HCO_3^-	NO_3^-	Cl^-	SO_4^{2-}
pH	1										
EC	-0.61	1									
TDS	-0.38	0.83	1								
Ca^{2+}	0.12	0.26	0.41	1							
Mg^{2+}	-0.35	0.70	0.85	0.68	1						
Na^+	-0.42	0.77	0.89	0.47	0.92	1					
K^+	-0.27	0.66	0.65	0.12	0.66	0.74	1				
HCO_3^-	-0.08	0.41	0.29	0.25	0.31	0.30	0.55	1			
NO_3^-	-0.41	0.35	0.50	0.23	0.63	0.72	0.37	-0.11	1		
Cl^-	0.02	-0.09	-0.01	0.22	0.19	0.05	-0.06	-0.27	0.05	1	
SO_4^{2-}	0.28	-0.41	-0.51	-0.34	-0.37	-0.24	-0.08	-0.10	-0.05	0.19	1

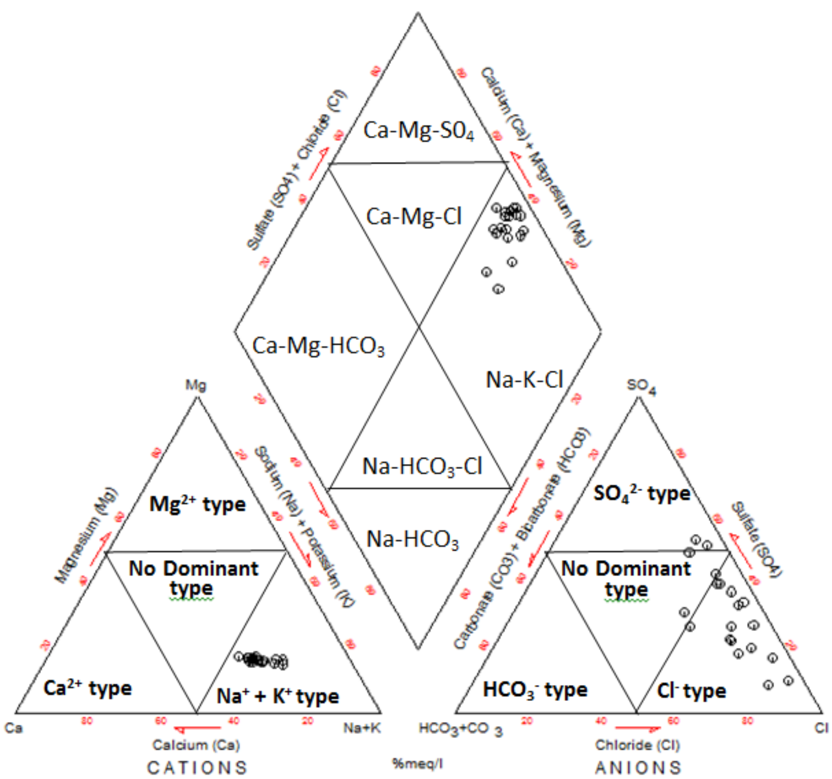

Figure 3: Piper diagram showing the hydrochemical facies of the water samples from Oba Dam

Water Quality Index (WQI) and Suitability Assessment for Drinking and Domestic Uses

The calculated water quality index for the studied water samples from Oba dam ranged between 15 and 21 with an average value of 17. All the analysed water samples fall in the 'Excellent' class (WQI < 25; Shweta *et al.*, 2013) of water quality rating. The controlling chemical parameters of the WQI are pH, TDS, EC, Na^+, Ca^{2+}, K^+, Mg^{2+}, SO_4^{2-}, NO_3^- and HCO_3^-. All the parameters are within the permissible limits of WHO (2011) drinking water standard, which suggests that the surface water in Oba Dam is not contaminated by the ions. Spatial variation of pH and TDS indicates that water samples close to the embankment have lower pH and higher TDS but still safe for drinking purposes (Figure 4). Low pH levels which indicate weak acidic water have potential to enhance corrosion of pump parts. It may also increase dissolution of trace metals from bottom sediments and country rocks (Brady, 1984). Lower pH values in water samples close to the embankment may be due to increased production of CO_2 from microbial respiration (Pelig-Ba *et al.*, 1991) as the area may be more conducive for microbial growth due to very low water current. High TDS may imparts bad taste, odour and unfavourable physiological reactions in consumers (Spellman and Drinan, 2000). Higher TDS values recorded in water samples picked close to the embankment may be due to increased dissolution of solids like sediments and rocks. Spatial distributions of major ions show higher contents of Na^+, Mg^{2+}, K^+, HCO_3^-, SO_4^{2-} and NO_3^- in water samples picked at the southern and middle areas of the reservoir separated (Figure 4). Mg, K, and Na contents in water may be sourced through weathering of rock forming minerals. High content of NO_3^- may be due to water contamination from organic effluents like household sewage and septic tanks and animal dungs leachates. Akintola and Gbadegesin (1997) also observed high NO_3^- content in water of Oba Dam which is attributed to effect of land-use change around the dam area from forest to cultivated land. Another reason suggested is the increasing use of fertilizer in the farms around the dam. This resulted in the increase of nitrate levels in the water as the excess nitrate from the fertilizer is washed down into the dam.

Suitability Assessment for Irrigation Use

Sodium absorption ratio (SAR): The SAR values for the analysed water samples from Oba Dam range from 0.76 to 1.25. This shows that surface water in Oba dam is excellent for agricultural irrigation as all the water samples have SAR values below 10.

Percent sodium (%Na): The %Na values of the analysed water samples ranges between 36.11 and 44.90 with an average of 39.99. Based on %Na water class, 50% of the samples have values below 40 and are thereby classified as good for irrigation purpose. On the contrary, the other 50% of the samples have values above 40 and are classified as doubtful for agricultural irrigation. Irrigation water containing high contents of Na^+ will results in reduction of soil permeability, thereby limiting air and water circulation within the soil.

Keller index (K1): The calculated K1 values for the analysed samples range between 0.75 and 1.28 with an average of 0.97. 70% (14 samples) of the studied samples have values below 1 and classify as suitable for irrigation, while 40% (6 samples) have values above 1 and classify as unsuitable for irrigation. The evaluation results based on %Na and K1 indexes indicate that the influence of Na^+ content on irrigation suitability of water in Oba Dam cannot be ignored.

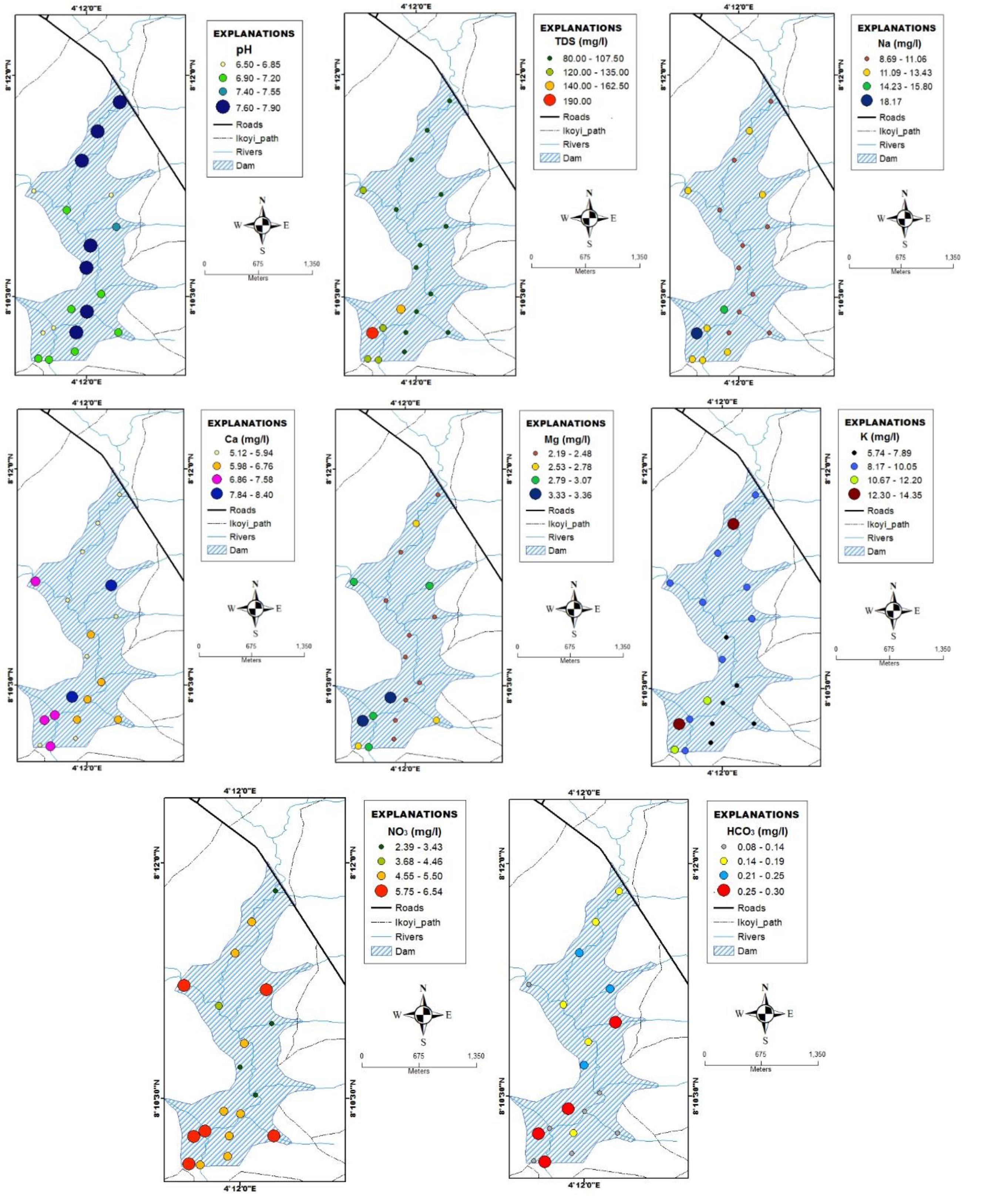

Figure 4: Spatial distribution of pH, TDS, Na^{+}, Ca^{2+}, Mg^{2+}, K^{+}, NO_3^{-} and HCO_3^{-} in water samples from Oba Dam

Conclusion

The surface water in Oba Dam, Ogbomoso is fresh, circumneutral to weak alkaline and soft in nature. The cations content is dominated by Na^+ and K^+, while the anions abundance is dominated by NO_3^- and Cl^-. In all the analysed samples, alkali metal cations (Na^++K^+) exceed alkaline earth metals (Ca^{2+}+Mg^{2+}) while strong acid (SO_4^{2-}+Cl^-) dominates of weak acid (HCO_3^-). The Na^{+-}-K^+-Cl^- water facie nature of the water samples suggest that chemical composition is controlled by anthropogenic sources. Overall, the surface water in the reservoir of Oba Dam is suitable for drinking, domestic and irrigation purposes without treatment. However, there is need for regular monitoring of sodium content in the water to determine suitability for irrigation purpose.

Acknowledgement

Authors would like to thank the management and staffs of Oyo State Water Corporation, Ogbomoso District Office for given permission to have access to the study site. Our appreciation to the anonymous reviews for their valuable contributions to improve the quality of the manuscript.

References

Abegunrin, T.P., Awe, G.O. and Adejumobi, M.A. (2016). Water quality status of three different rivers in Fadama-oriented irrigated Agriculture in Ogbomoso, Southwest Nigeria. *Archives of Current Research International, 3(3), 1-16.*

Akintola, F.O. and Gbadegesin, A. (1997). Land-use changes and water quality in impounded water-supply dams in southwest Nigeria. *Freshwater Contamination (Proceedings of Rabat Symposium S4)*, JAHS Publication no. 243, 313-319.

APHA (2005). Standard Methods for the Examination of Water and Wastewater, 21st ed., A publication of American Public Health Association, Washington DC, 1467p

Aquilina, L., Sureau, J. F., & Steinberg, M. (1997). Comparison of surface-, aquifer- and pore-waters from a Mesozoic basin and its underlying Paleozoic basement, southeast France: Chemical evolution of waters and relationships between aquifers. *Chemical Geology*, 138, 185–209

Batabyal, A.K. and Chakraborty, S. (2015). Hydrochemistry and Water Quality Index in the Assessment of Groundwater Quality for Drinking Uses. *Water Environment Research*, 87(7), 607-617.

Brady, N.C. (1984). Nature and Properties of Soils (8th edition), Macmillan Publishers Co., New York, 750p.

Cao, X., Lu, Y., Wang, C., Zhang, M., Yuan, J., Zhang, A., Song, S., Baninia, Y., Khan, K., Wang. Y. (2019). Hydrogeochemistry and quality of surface water and groundwater in the drinking water source area of an urbanizing region. *Ecotoxicology and Environmental Safety, 186, 1-8. https://doi.org/10.1016/j.ecoenv.2019.109628*

Cassardo, C. and Jones, J.A.A. (2011). Managing water in a changing world. *Water*, 3, 618–628. https://doi.org/10.3390/w3020618

Du Plessis, A. (2017). Global water availability, distribution and use. In: Freshwater Challenges of South Africa and its Upper Vaal River. Springer Water. Springer, Cham, 3-11. https://doi.org/10.1007/978-3-319-49502-6_1

Freeze, R. A. and Cherry, J. A. (1979). Groundwater. Prentice-Hall, Englewood Cliffs, 604p.

Garrels, R. M. and Mackenzie, F. T. (1967). Origin of the chemical composition of some springs and lakes. In: W. Stumm (Ed.), Equilibrium concepts in natural water systems (pp. 222–242), Washington, DC: American Chemical Society. (Chap. 10)

Kawo, N.S. and Karuppannan, S. (2018). Groundwater Quality Assessment Using Water Quality Index and GIS Technique in Modjo Basin, Central Ethiopia. *Journal of African Earth Sciences*, 147, 300-311. doi: 10.1016/j.jafrearsci.2018.06.034

Kumar, P. and Sing, A.K. (2020). Hydrogeochemistry and quality assess of surface and sub-surface water resources in Raniganj coalfield area, Damodar valley, India. *International Journal of Environmental Analytical Chemistry, DOI: https://doi.org/10.1080/03067319.2020.1849653*

Mather, J.R. (1984). Water Resources: Distribution, Use and Management. John Wiley and Sons Incorporated, New York, 439p.

Neal, C. and Shand, P. (2002). Spring surface water quality of the Cyprus ophiolites. *Hydrology and Earth System Sciences*, 6, 797–817.

Ojelabi, S.A., Agbede, O.A., Wahab, B.A., Aiyelokun, O.A., Ojelabi, O.A., (2018). Water Quality Assessment of Eleyele Dam, Ibadan, South-Western Nigeria. *Civili and Environmental Research*, 10 (8), 52-59.

Pelig-Ba, K.B., Biney, C.A. and Antwi, L.A. (1991). Trace metal concentrations in borehole water from the Upper regions and the Accra Plains of Ghana. *Water, Air, Soil Pollution*, 59, 333-345.

Piper, A. M. (1944). A graphical procedure in the geochemical interpretation of water analysis. *Trans Am Geophys Union*, 25, 914–928.

Richard, L.A. (1954). Diagnosis and improvement of saline and alkalis soils. Agric. Handbook 60, U.S. Department of Agriculture, Washinton, D.C., 160p.

Shweta, T., Bhavotosh, S., Prashani, S., Rajendra, D. (2013). Water Quality Assessment in Terms of Water Quality Index. *American Journal of Water Resources*, 1(3), 34-38. doi: 10.12691/ajwr-1-3-3.

Spellman, F.R., Drinan, J. (2000). The Drinking Water Handbook, CRC Press, New York, 274p.

Standard Organisation of Nigeria (SON), (2015). Nigerian Standard for Drinking Water Quality. SON Publication, Abuja, Nigeria, 28pp. *www.health.gov.ng*

Subramani, T., Elango, L. and Damodarasamy, S.R. (2005). Groundwater quality and its suitability for drinking and agricultural use in Chithar River Basin, Tamil Ndu, India. *Environmental Geology*, 47, 1099-1110.

Tijani, M.N. and Onodera, S. (2009). Hydrogeochemical Assessment of Metal Contamination in an Urban Drainage System: A Case Study of Osogbo Township, SW Nigeria. *Journal of Water Resource and Protection*, 3, 164-173.

Tiwari, A.K., Singh, A. K, Singh, A.K. and Singh, M.P. (2017). Hydrochemical analysis and evaluation of surface water quality of Paratapgarh District, Uttar Pradesh, India. *Applied Water Science,* 7, 1609-1623.

World Health Organization, WHO (2011). Guidelines for Drinking-Water Quality, 4th ed., vol. 1. World Health Organisation, Geneva, Switzerland.